

the MES on the ground directly below the aircraft; the other with the aircraft at a 45° elevation angle when viewed from the MES.

The results of the calculation showed that the $C/(N_0+I_0)$ would be greater than 30 dB-Hz in both cases, corresponding to an $E_b/(N_0+I_0)$ greater than 13 dB and a bit error rate of less than 10^{-6} for uncoded GLONASS transmissions. It was estimated that within the 120 square mile area for which the elevation angle was greater than 45°, there would on average be only one user about 20 percent of the time.

The conclusion was that CDMA MES users would not interfere with en route GLONASS navigation at altitudes above 10,000 m. However, aviation interests in the Committee stated that this analysis, based on a U.S.-wide average user MES density, was inadequate to demonstrate interference compatibility at a 95 percent confidence level, a minimum for aviation safety services.

The second analysis assumed a more general scenario for en route navigation which made no specific assumption about aircraft altitude. Instead, it calculated the required separation between the MES and the aircraft to ensure a maximum interference level of -190 dBW/Hz at the GLONASS receiver, assuming free space propagation between isotropic (unity gain) antennas. Separation ranges were calculated for each of the CDMA MSS/RDSS applicants, assuming an e.i.r.p. density obtained by dividing the applicant's e.i.r.p. by the corresponding signal bandwidth. The resultant separation distances ranged from 12.3 km to 83.2 km.

3.3.4.4 Analysis of the availability of GNSS satellites (DG2B Report §2.1.3.1.4)

Computer simulations were performed to examine the availability of the GNSS satellite constellation based on the orbits and operating status of the GPS and GLONASS satellites. The number of satellites visible at an elevation angle of at least 5° at a CONUS mid-latitude site was noted for 5-minute intervals over a 51-day period, assuming that the GPS constellation included 22 of the available 24-satellite maximum and that the GLONASS constellation was truncated to include only 12 of the 14 satellites with center frequencies below 1610 MHz.

The results of the simulation indicated that a minimum of five satellites were always visible and that this minimum occurred for a total of only 14 minutes out of the simulated 51-day period. Since only four GNSS satellites are required for navigation, and a fifth satellite to ensure system integrity, it appeared that GLONASS satellites operating above 1610 MHz might not be required either for navigation or terminal approach.

3.3.4.5 Conclusions regarding the feasibility of frequency sharing in interference case 5 (DG2B Report §3)

Although the calculations described in §3.3.4.3 above indicated that GLONASS receivers on aircraft at slant ranges of 12,000 m from an MES might be protected, it is clear that based on current technology, MSS systems cannot meet the MES e.i.r.p. density levels

(e.g., no more than -78 dBW/MHz for cochannel operation) specified by the aviation community for the protection of aeronautical radionavigation using GLONASS at spacings as small as 100 m.

Based on the analyses reported in the preceding subsections and on the respective technical and operational requirements of the aviation community and MSS operators, it appears that the prospects for compatible cochannel operations in the 1610-1616 MHz band occupied by GLONASS are limited.

Nonetheless, the Committee has been able to identify several potential actions that may be used to improve the sharing prospects. These are described in §§3.3.4.6 and 3.3.4.7 below.

3.3.4.6 Possible GLONASS actions to improve the sharing environment (DG2B Report §3.1)

3.3.4.6.1 Re-use frequencies on antipodal GLONASS satellites (DG2B Report §3.1.1)

Unlike GPS, which uses one universal carrier frequency with different coding for each satellite, each GLONASS satellite utilizes a separate, individual downlink transmit carrier frequency. With 24 satellites in the full GLONASS constellation, there are planned to be 24 discrete frequencies in use simultaneously. However, in the satellites currently under construction for GLONASS replenishment, the satellite downlink frequency assignments are programmed by telecommand from the ground control station. Thus, it is assumed that each of the new GLONASS-M satellites has the capability of operating on any of the 24 frequencies between 1602 and 1615.5 MHz.

Because of this frequency agility, it may be possible that some of the satellites, while on opposite sides of the earth, could use the same frequencies without causing self-interference. By reusing frequencies on antipodal satellites, the 24 GLONASS satellites could operate entirely on the 12 frequencies below 1610 MHz. This would result in each orbital plane of 8 satellites occupying only 4 carrier frequencies.

This reconfiguration of the GLONASS frequency plan would have many benefits.

- It avoids all in-band mutual interference with MSS uplinks
- With appropriate filtering of the GLONASS transmitter, it avoids interference to the RAS in the band 1610.6-1613.8 MHz.
- It would benefit the aviation and INMARSAT communities by eliminating stringent filtering requirements in the SATCOM terminal diplexer now required to protect GLONASS receivers on the same aircraft.

The Committee's analysis of the impact of the suggested reconfiguration on the GLONASS system is that it would be acceptably small. The inherent frequency agility of the newer GLONASS satellites makes it possible to operate on 12 frequencies rather than 24 without affecting the satellite design. And, although it would be

necessary to replace older Russian-built receivers, the required changes to the receiver circuitry are straightforward, as explained in detail in DG2B Report §3.1.1.

Finally, the aeronautical community has indicated that they would have no fundamental objection to the reconfiguration.

3.3.4.6.2 GLONASS frequency shifting plan (DG2B Report §3.1.2)

A more radical approach to removing the GLONASS frequencies from the 1610-1626.5 MHz band is to shift all 24 GLONASS frequencies by about 11.5 MHz to lie below 1610 MHz but still above the adjacent GPS frequency assignments. This would offer the same benefits as the reuse of GLONASS frequencies on antipodal satellites, but could require system redesign.

3.3.4.6.3 Enhanced receiver standards (DG2B Report §3.1.3)

With the advance notice the MSS systems will be deploying satellites in the 1610-1616 MHz band by 1997, the aviation community, including the GLONASS and GPS and aeronautical receiver manufacturers, should be encouraged to modify GLONASS receiver performance standards in order to reduce GLONASS's vulnerability to in-band interference from MSS. It is noted that the AEEC has recently proposed more stringent standards (from 13 to 21 dB for interference rejection).

It is also noted that this approach is unlikely by itself to provide enough additional rejection to enable MSS systems to protect GLONASS to the degree desired by aviation. Nevertheless, it may be helpful if employed in conjunction with other interference mitigation techniques.

3.3.4.6.4 Revision of proposed aviation reliance of GLONASS as a component of GNSS (DG2B Report §3.1.4)

The aviation community has stated that it must use both GPS and GLONASS to provide the necessary integrity and availability it requires for a GNSS on which reliance is placed. The Committee suggests that the aviation community consider alternatives to the sole means reliance on GLONASS. Such alternatives include additional GPS satellites, use of navigational packages on geostationary satellites to validate and supplement GPS, and other means of augmenting GPS.

If MSS is to operate on a cochannel basis with GLONASS, the aviation community must diminish its anticipated reliance on this system as a part of the GNSS.

3.3.4.7 Other approaches

The Committee examined the following three additional approaches to reducing the sharing problems associated with interference case 5, but none were considered to be nearly so effective or easy to implement as the GLONASS actions described in the previous section.

3.3.4.7.1 Maximum permissible e.i.r.p. density from handheld MES terminals (DG2B Report §3.2)

The objective of defining a maximum permissible e.i.r.p. or e.i.r.p. density for MSS terminals operating cochannel with GLONASS is to ensure that the GLONASS user will have sufficient margin to operate successfully. However, there is a very large disparity between the value in RR 731E (-15 dBW/4kHz) and the values proposed by the aviation community to protect GLONASS receivers within as little as 100 m of an MES terminal. As a result, specification of an uplink e.i.r.p. limit will not resolve the sharing issue.

3.3.4.7.2 Protection zones (DG2B §3.3)

Another approach examined by the Committee was the concept of exclusion or protection zones around critical GLONASS operational areas such as the final approach paths into airports and en route navigation paths. However, given the protection ranges calculated in §3.3.4.3 above, fixed protection zones would exclude MES from nearly all of CONUS.

A beacon-actuated protection zone would somewhat reduce the size of the zone along en route paths, but is considered impractical due to the high cost of beacon installation and maintenance. On balance, the protection zone concept appears to be both difficult and expensive.

3.3.4.7.3 Repositioning the MSS user frequency (DG2B Report §3.4)

Another possible approach to protecting GLONASS would be to utilize an avoidance mechanism under the control of the MSS system operator. This mechanism would prevent MESSs from transmitting on specific GLONASS frequencies in the 1610-1616 MHz band. However, the approach requires accurate information on the position of the MES before assigning it to transmit on a channel in the 1610-1616 MHz band.

A description of how this approach might be implemented is given in DG2B Report §3.4. While acknowledging that the approach is complicated, the Committee believes that it warrants further study.

3.3.5 Case 5R - Protection of MSS/RDSS Systems from GLONASS (including GLONASS-M) in the 1610-1621 MHz Band (DG2B Report §2.2)

The satellites of the GLONASS system currently transmit at frequencies on which MSS satellites would like to receive uplink transmissions from MESSs. Thus, there are space-to-space paths on which the GLONASS system can interfere with MSS uplinks. The problem is exacerbated by the fact that there is no regulatory limit on the PFD used by GLONASS and the possibility that the advance-published e.i.r.p. levels for GLONASS may understate the actual power levels.

Because not all system applicants plan to use low-earth-orbit (LEO) satellites, the Committee analyzed two types of interference

geometries: uplinks to geostationary MSS satellites and uplinks to non-geostationary MSS satellites. In both cases, the advance-published GLONASS e.i.r.p.s were assumed; therefore, the results may be overoptimistic.

In the geostationary case, the only MSS uplink channels that would suffer unacceptable interference were CDMA channels operating below 1616 MHz.

In the case of LEO MSS systems, no examples of unacceptable interference were found.

3.3.6 Case 6 - Protection of GLONASS in the 1610-1616 MHz Band from Secondary MSS Downlinks in the 1613.8-1626.5 MHz Band (DG2B Report §2.3)

Motorola's IRIDIUM system is the only MSS applicant planning to use the secondary MSS downlink allocation at 1613.8-1626.5 MHz. The GLONASS system will be protected against harmful interference from IRIDIUM downlinks by five mechanisms: 1) band separation; 2) controlled out-of-band emissions; 3) a guard band in some circumstances; 4) a comprehensive analysis and testing program; and 5) international coordinations.

Some of these mechanisms was briefly elaborated in §3.2.5.3 of this report in connection with the protection of the RAS under interference case 3.

3.3.7 Case 7 - Protection of ARNS and RNSS below 1610 MHz from Out-of-Band Emissions by MSS/RDSS Uplinks in the 1610-1626.5 MHz Band (DG2B Report §2.5)

Two types of scenarios have to be considered under this interference case: 1) interference to airborne radionavigation in the vicinity of final approach to an airport; and 2) interference to ground-based public safety users of GNSS signals such as the GPS standard positioning service (SPS) centered at 1575.42 MHz.

Before summarizing the Committee's analyses of these two cases, it should be recalled from the description of the GPS space segment in §3.3.2 above that the GPS satellites orbit at an altitude of 20,168 km and their signals at the earth's surface are -160 dBW from a 3 dB linearly polarized antenna. Hence, they are vulnerable to out-of-band emissions near 1575 MHz from MES located in close proximity to a GPS navigation receiver.

3.3.7.1 Discussion of interference to airborne GPS navigation of final approach paths (DG2B Report §§2.5.2, 2.5.4)

Interference can influence GPS in two ways on final approach: 1) disrupting reception at the ground-based differential GPS receiver site, and 2) disrupting GPS reception aboard the aircraft. The use of differential GPS is necessary to achieve position determination with the required accuracy of a few meters.

For the former type of interference, physical separation of the MES uplink terminal from the differential GPS receiver and control of out-of-band emissions from the MES are the principal means of control. A calculation of required separation based on the out-of-band filtering characteristics of the INMARSAT-C MES terminal is presented in DG2B Report §2.5.4. It suggests that separations of tens of meters will suffice.

For interference to the aircraft GPS receiver, the geometry of the interference path is different since the aircraft is normally at a higher altitude than the MES terminal. As a result, there will be some shielding from the aircraft wings and body.

3.3.7.2 Discussion of interference to ground-based public safety users (DG2B Report §2.5.3)

Here the GPS navigation receivers are mounted on vehicles such as police cars, fire trucks, and ambulances. As a result, the MES transmitter and the GPS receiver are likely to be at the same height and only a few meters apart (e.g., the width of a highway lane). However, the relative vehicle motion should bring the public safety vehicle within interference range only for a short time. This relative motion allows some improved rejection through navigation solution averaging in the GPS receiver. Suppression of out-of-band emissions at the MES transmitter is also important.

3.3.8 Case 8 - Protection of the ARNS and RNSS below 1610 MHz from Out-of-Band Emissions by Secondary Downlinks in the 1613.8-1626.5 MHz Band (DG2B Report §2.5)

The Committee concluded that interference from L-band MSS secondary downlinks to GPS reception will be negligible because of the low level of MSS satellite signals (-139 dBW/m²) and the large frequency separation involved.

3.4 Sharing between the MSS/RDSS and Services Other Than the RAS and ARNS/RNSS

3.4.1 Relevant Frequency Allocation and Interference Cases To Be Considered

The radiocommunication services and frequency allocations which may cause interference to, or be subject to interference from, MSS/RDSS systems are those listed in Table 3-1 for interference cases 9 through 16 and 9R through 15R. The characteristics of the systems that use each allocation will be included in the discussion of the sharing problems and sharing approaches for the corresponding interference case.

3.4.2 Cases 9 and 9R - Sharing between the Fixed Service (FS) Operating under RR 730 and MSS/RDSS Uplinks in the 1610-1626.5 MHz Band (DG2C Report §§3.1, 3.2, 5.1, 5.2.1.4)

The FS has a primary allocation that includes the 1610-1626.5 MHz band only in the 20 pre-1990 countries cited in RR 730 (MOD WARC-92).

These include 11 in Europe (FR Germany, Austria, Bulgaria, Spain, France, Hungary, Poland, the German DR, Romania, Czechoslovakia, and the USSR), 7 in Africa (Cameroon, Guinea, Libya, Mali, Nigeria, Senegal, and Tanzania), and 2 in Asia (Indonesia and Mongolia). Thus, this sharing case does not pertain to the U.S. or other Region 2 countries.

A search of the ITU International Frequency List revealed only one FS system registered in the 1616-1626.5 MHz band. The Committee was not able to obtain more complete information about other non-military FS systems that might be operating under RR 730. However, the Committee was informed that seven of the eight NATO European countries using the 1610-1626.5 MHz band for military communications under RR 730 have recently indicated that they will withdraw from use of this band before MSS operations commence. The U.S. Army in Europe intends to vacate the band by 1 October 1993.

In RR 730 countries where FS systems do operate, MSS/RDSS system operators should be able to avoid L-band interference from their uplinks by employing protection zones around existing FS locations. In addition, some MSS applicants will be able to avoid interference by using narrow band transmissions and alternative frequencies in coverage areas where other services are operating in foreign countries.

MSS operators should be able to coordinate MSS uplinks with foreign administrations by agreeing to accept a protection zone sufficient to protect an operating point-to-point FS link. MSS receivers should be able to obtain a position signal from the satellite to avoid transmissions in these protection zones. If the MSS transmitter is within the protection zone, potential interference could be avoided by either ceasing transmission or by operating on a frequency not used by the FS operator.

3.4.3 Cases 10 and 10R - Frequency Sharing between Secondary FS Systems (Operating under RR 727) and Secondary MSS Downlinks in the 1613.8-1626.5 MHz Band (DG2C Report §§3.2.2, 5.2.1)

In addition to the 20 countries where the FS has a primary allocation under RR 730, there are 29 countries, mostly in Africa, where it has a secondary allocation under RR 727. However, the International Frequency List does not identify any such systems, and the Committee was unable to obtain information about foreign FS systems that might be operating under RR 727.

If there are RR 727 countries where such systems do exist, proposed MSS systems operating downlinks in the L-band should be able to avoid potential mutual interference by using narrow band transmissions and different frequencies in coverage areas. MSS systems can also rely upon the new international notification and coordination procedures of Resolution 46 (WARC-92) and mandated for secondary MSS downlinks by RR 731F (WARC-92) to identify and resolve particular sharing and interference concerns of other administrations.

Coordination with systems operating in the FS could be accomplished by a number of means, depending upon the number of systems in operation, the frequencies they use, and where they are located. For example, in light of the relatively large amount of spectrum in the RR 727 FS allocation (over 100 MHz), it may be possible to move these systems outside the affected band (less than 13 MHz). Interference could also be avoided through frequency agility in the MSS downlink transmissions by selecting frequencies in certain spot beams not expected to interfere with the fixed service system. It may also be possible to avoid specific geographic locations by controlling the downlink spot beam coverage.

3.4.4 Cases 11 and 11R - Frequency Sharing between the FS or MS and MSS Downlinks in the 2483.5-2500 MHz Band (DG2C Report §4.2)

According to the FCC database, there are 737 licensed FS stations operating in the U.S. in the 2483.5-2500 MHz band. In some cases, multiple transmitters may operate under the same link. As of the mid-1980s, the FCC Rules for terrestrial services prohibit any increase in the number of licensed terrestrial transmitters. The most prevalent domestic uses of such stations are for microwave relay systems serving petroleum companies and for broadcast auxiliary links. The key technical parameters of these systems are given in §4.2.1 of the DG2C Report.

Outside the United States, the International Frequency List (IFL) indicates a total of 128 registered FS assignments as of September 1991. It should be noted, however, that the IFL generally does not reflect the full extent of frequency band usage for the FS.

3.4.4.1 Interference to the FS from MSS downlinks

The power flux density (PFD) generated by MSS/RDSS spacecraft, in excess of levels prescribed by RR 2566, may result in interfering signals at the receiver input of stations in the FS. The likelihood that these interference levels exceed acceptable levels may be different for geostationary and non-geostationary satellite networks. This interference mechanism is system specific (for both FS and MSS) and can best be addressed during coordination. To eliminate the need to coordinate with other administrations, the MSS/RDSS spacecraft transmission should not exceed the international PFD limits.

3.4.4.2 Interference to MSS downlinks from the FS

No analyses were provided to quantify the sharing constraints needed to prevent interference to mobile earth stations from domestic terrestrial facilities in the 2483.5-2500 MHz band. The practicality of moving these terrestrial facilities in other bands was not assessed.

Based on assignments in the International Frequency List and the coordination distances specified in Resolution 46 for mobile earth stations operating in the 2483.5-2500 MHz band (i.e., 500 km and 1000 km for ground-based and airborne mobile earth stations), coordination will be needed to determine the potential levels of interference from

foreign stations operating in the fixed service. For mobile earth station operation in or over the U.S., coordination will be needed with Canada, Mexico, and Russia. For operation of mobile earth stations outside the U.S., operator coordination will be needed with Argentina, Austria, Belgium, Canada, Chile, Peoples Republic of China, Germany, Spain, France, Netherlands, Iran, Kuwait, Mexico, Malta, Czech and Slovak Federal Republics, Russia, Turkey, and Yugoslavia, as well as other administrations that may seek to notify fixed service assignments in the 2483.5-2500 MHz band.

3.4.5 Cases 12 and 12R - Out-of-Band Interference between the FS or MS Operating below 2483.5-2500 MHz and MSS/RDSS Downlinks in the 2483.5-2500 MHz Band (DG2C Report §2.6)

The Committee obtained the FCC data base listing of the FS and MS stations operating in the U.S. below 2483.5 MHz. It concluded that any out-of-band sharing problems between the MSS and the broadcast auxiliary service below 2483.5 MHz were likely to be sporadic and inconsequential.

3.4.6 Cases 13 and 13R - Out-of-Band Interference between the FS above 2500 MHz and MSS/RDSS Downlinks in the 2483.5-2500 MHz Band (DG2C Report §4.7)

In the U.S. the FS allocation above 2500 MHz is used for the instructional television fixed service (ITFS) and microwave multipoint distribution service (MMDS). Transmissions in both services are similar to those of broadcast television and employ 6 MHz channels at e.i.r.p.s between 20 and 37 dBW from antennas with narrow horizontal omnidirectional or cardioid patterns. The lowest ITFS/MMDS channel (2500-2506 MHz) is contiguous with the MSS/RDSS downlink band, with cochannel and adjacent channel stations separated by a minimum of 50 miles. Current FCC requirements specify that out-of-band emissions be at least 60 dB below the ITFS/MMDS carrier.

With an e.i.r.p. comparable to an MSS spacecraft, an MDSS transmitter can produce a signal just above 2500 MHz whose PFD at an MES receiver 1 km away is 70 dB higher than the maximum PFD that the MSS spacecraft can produce. It may be concluded that out-of-band interference from MSS downlinks into the FS above 2500 MHz (case 13) is not a problem. On the other hand, interference in the reverse direction (case 13R) will be a serious problem unless MMDS out-of-band emissions from the lower channel are suppressed by much more than the current 60 dB requirement.

The Committee concluded that out-of-band emissions from the lowest channel should be limited to -90 dB relative to the carrier at a frequency offset from band edge between 1.25 and 2 MHz, assuming that the channel is operating at 30 dBW e.i.r.p. Adjustments could be made for higher frequency channels and for higher or lower operating e.i.r.p.s. ITFS/MMDS operators acknowledge that they can improve suppression to this level at 2498.75 MHz but that the additional cost per station will be from \$10,000 to \$30,000 with today's analog NTSC signals.

For tomorrow's stations, which will emit compressed digital video signals, the cost per station likely will be more; the phase delay errors must be corrected far more carefully. Some stations will convert to digital within the next two years and most, we believe, within the decade.

The cost for the improvement of suppression can be reduced appreciably if the target frequency for -90 dB suppression is shifted from 2498.75 MHz to a slightly lower target frequency, such as 2497.7 MHz (attenuation slope not over 22 dB per MHz, as already incorporated in the FCC Rules).

3.4.7 Cases 14 and 14R - Out-of-Band Interference between the Broadcasting-Satellite Service (BSS) or Fixed-Satellite Service (FSS) Operating above 2500 MHz and MSS/RDSS Downlinks in the 2483.5-2500 MHz Band (DG2C Report §4.6)

Space-to-Earth links operating in the BSS or FSS in the 2500-2655 MHz band are subject to the PFD limits of RR 2562, and the PFD of emissions falling in the 2483.5-2500 MHz band can be expected to be substantially lower than the RR 2562 levels. Thus, although the PFD allowed under RR 2562 is up to 5 dB greater than the RR 2566 PFD threshold for MSS/RDSS systems in the 2483.5-2500 MHz band, it can be expected that no unacceptable interference will result from this adjacent band sharing. Out-of-band interference from downlinks operating above 2500 MHz into MSS downlinks below 2500 MHz is expected to be at acceptable levels, and vice versa.

3.4.8 Cases 15 and 15R - Frequency Sharing between the Radiolocation Service (RLS) and MSS/RDSS Downlinks in the 2483.5-2500 MHz Band (DG2C Report §§4.3, 4.4, and 4.5)

In the U.S., the RLS is allocated in this band for government use only on a non-interfering basis (footnote US 41) and so interference to and from U.S. RLS systems is not an issue.

No quantitative analyses of the potential interference from MSS/RDSS satellites to radiolocation receivers were provided. However, it is possible that the PFD constraints needed to protect the fixed service also will adequately protect stations in the radiolocation service, including stations operating under footnote US 41. Coordination could be required in the event that the RR 2566 PFD thresholds are exceeded.

No analyses were provided to quantify the sharing constraints needed for protection of mobile earth stations from foreign radio location transmitters. However, based on assignments in the International Frequency List and the coordination distances for mobile earth stations operating in the 2483.5-2500 MHz band, operator coordination will be needed to determine the potential levels of interference from foreign stations operating in the radiolocation service and to seek protection from those stations. The 500 km and 1000 km coordination distances in Resolution 46 pertain. For protection of mobile earth station operations in or over the U.S. and

abroad, coordination will be needed with Canada and France (St. Pierre & Miquelon).

3.4.9 Case 16 - Protection of MSS/RDSS Downlinks in the 2483.5-2500 MHz Band from Interference from Industrial, Scientific, and Medical (ISM) Emissions (DG2C Report §4.8)

The 2400-2500 MHz band is allocated internationally by ITU footnote 752 and domestically by Part 18 of the Commission Rules for use by Industrial, Scientific, and Medical (ISM) applications. ISM uses include microwave ovens, door openers, high frequency lighting systems, industrial equipment, and other low-powered devices such as wireless communication devices. It is estimated that there are over 80 million microwave ovens currently in operation in the U.S., with over 200 million microwave ovens worldwide. Industrial equipment, high-efficiency lighting systems, and wireless communications devices (e.g., R-LANs) are also increasing the use of the ISM band in the U.S. and abroad.

The Committee was unable to reach consensus on this matter. LQSS and Motorola submitted separate analyses of ISM interference which are included as Addenda to this Report and to the DG2C Report.

4.0 FEEDER LINK AND INTER-SATELLITE LINK OPERATIONS

Under the work program established by the Committee, Working Group 3 was tasked to recommend modifications or new rules to the FCC Rules as may be necessary to accommodate feeder link and inter-satellite link operations for MSS/RDSS systems, in particular with respect to ITU Radio Regulation 2613. The Committee's conclusions are set out in this section. The report of Working Group 3 to the Committee is attached as Annex 3. It contains a more extensive analysis of these issues and as a consequence includes, in some instances, a more detailed treatment of conclusions and proposals.

The term "LEO", for low-Earth orbit, appears throughout this section to describe, albeit imprecisely, a non-geostationary satellite. The term "GSO" is used to describe a satellite in geostationary orbit. The fixed-satellite service (or "FSS"), both domestically and internationally, also includes feeder links for the MSS/RDSS.

4.1 Feeder Link Requirements, General Geostationary/Non-Geostationary Sharing Situation, and International Coordination Obligations

The Committee examined a number of generic issues that relate to sharing of frequency bands by LEO and GSO satellite systems. First, the Committee analyzed the likelihood that there would be beam coupling between a GSO earth station antenna and a LEO satellite antenna. It concludes that while such beam coupling is likely to occur -- depending on the extent to which GSO satellite networks exist in the frequency bands to be shared -- the coupling time statistic is relatively short.

Although the Committee did not determine whether and when beam coupling would lead to an increased potential for harmful interference, it did identify coordination procedures, and MSS/RDSS system and satellite-antenna designs that could either eliminate beam coupling or reduce the coupling time statistics. The latter include LEO satellite feeder uplink site diversity; narrow beam LEO satellite antennas; steerable spot beam LEO satellite antennas; and relatively large LEO and GSO earth station antenna size. The Committee concludes that through the use of these and other options, the coupling statistics could be reduced to as small as necessary.

The Committee recommends that if the interference situation warrants, it will be necessary to establish a set of balanced sharing principles and interference criteria, based in whole or in part on the options identified above, that would permit successful co-channel operation of both LEO and GSO systems. If the sharing principles to reduce beam coupling prove too restrictive, it may be necessary to explore other options -- such as the possibility of establishing geographic exclusion zones where GSO-FSS and/or LEO feeder link operations would be prohibited, or the use of dedicated frequency allocations for LEO satellite feeder link use.

The Committee conducted a comprehensive analysis of the obligations of the United States under RR 2613, and makes several specific recommendations as to how the U.S. Government should interpret and apply the regulation. With regard to international application of RR 2613, the Committee recommends at the outset that all applicants for non-geostationary satellite systems that propose to operate in frequency bands allocated to and used by geostationary FSS systems be apprised of the existence of the rule and its potential impact.

The Committee identified three conditions that must be met before a non-geostationary system would be required to cease or reduce transmissions in order to protect a geostationary system: (1) the administrations of the systems involve must engage in bi-lateral or multi-lateral discussions and reach agreement as to a level of "accepted interference" (see RR 162); (2) after the systems are in operation, the non-geostationary system must exceed the level of interference agreed to; and (3) the interference in excess of the agreed level must be caused by the failure of the non-geostationary system to maintain sufficient angular separation between the satellites of the two systems. If any of these three conditions is not met, RR 2613 cannot be invoked to affect the operations of any non-geostationary satellites. This interpretation of RR 2613 will provide an existing non-geostationary satellite system that operates in FSS bands with a necessary measure of protection against a demand from a future geostationary FSS system that they cease or reduce transmissions. The Committee recommends that the United States seek in appropriate international radio fora the adoption of procedures to afford balanced protection for non-geostationary systems from future geostationary systems. At the least the United States should seek to have the above interpretation of RR 2613 applied internationally.

No modifications to the Commission's rules would be needed with regard to international application of RR 2613. Section 25.111 requires applicants to provide the Commission with all information necessary to complete the IFRB processes, and subjects station licenses to additional terms and conditions pending the completion of applicable discussions with other Administrations. See 47 C.F.R. § 25.111(b).

On the domestic side, the Committee recommends that for purposes of the Commission's regulations, all that should be included for operators of non-geostationary and geostationary FSS systems licensed or to be licensed by the Commission is a requirement in Part 25 of the FCC's rules that affected operators coordinate their use of the shared bands. Domestic coordination would occur regardless of whether the geostationary FSS or non-geostationary system is the first to be operational. Obstacles to coordination might exist in the case of non-geostationary systems that propose to operate feeder links in frequency bands that are heavily populated by GSO-FSS systems. Conversely, coordination would be significantly easier for non-geostationary systems that propose to operate feeder links in frequency bands that are not heavily populated by GSO-FSS systems.

4.2 Feeder Links in the 5/6 GHz Bands

The frequencies proposed for use by three applicants in the Earth-to-space direction in these bands (6425-6725 MHz) are available for use as feeder links because they are allocated to the fixed-satellite service. No questions were raised during the NRM concerning the ability of the MSS/RDSS systems to share these bands with other fixed-satellite operations.

Three of the LEO MSS/RDSS systems above 1 GHz applicants have proposed the use of the 5150-5216 MHz band for feeder links operating in the space-to-Earth direction. These applicants have agreed that they can share the same spectrum for feeder links and will develop any necessary sharing arrangements amongst themselves.

The FAA opposes use of the 5150-5250 MHz band for LEO MSS feeder links. It is in the process of developing and implementing new navigation aids within the National Airspace System for this band. These include Differential Global Positioning System (DGPS), Terminal Doppler Weather Radar (TDWR) and Automatic Dependent Surveillance (ADS). The level of detail available on systems which are still in the conceptual stage was not sufficient to perform a detailed interference analysis. However, a preliminary review indicates that significant interference from DGPS, ADS and TDWR into LEO MSS feeder link downlinks may occur if the FAA planned systems are implemented. The aviation community believes that there may be difficulty using these bands for LEO MSS feeder links outside the United States because they are allocated on a worldwide basis to aeronautical radionavigation.

The Committee recommends that the FCC identify and/or allocate suitable spectrum below 15 GHz, and preferably below 10 GHz, for MSS/RDSS feeder links. A minimum of 66 MHz is required to

accommodate the three MSS/RDSS applicants that have developed system designs based on use of the 5150-5216 MHz band. A 100 MHz band for MSS/RDSS feeder links would allow for growth of system capacity as additional antenna beams beyond the eight per satellite assumed for RDSS are added in the 1.6/2.4 GHz bands for service links to user terminals. System architecture and service concepts dictate that the necessary spectrum be free of large populations of geostationary satellites and that it be possible to establish low-cost feeder link (gateway) earth stations in the United States without burdensome coordination with terrestrial services. The spectrum must also be available for use both within and outside the United States without significant international coordination restrictions because of the likely expansion of the MSS/RDSS systems to global service.

If the FCC determines that the 5150-5250 MHz band is the only spectrum below 15 GHz which can satisfy the identified MSS/RDSS feeder link requirements, the Committee recommends that the FCC take appropriate steps with the Interdepartment Radio Advisory Committee (which includes the FAA) and the National Telecommunications and Information Administration to identify conditions that could allow sharing of that band with aeronautical radionavigation.

The FCC should make appropriate modifications to the Table of Allocations in Part 2 of its Rules and appropriate modifications to Part 25 of its Rules if a change in allocations is required to make available suitable spectrum for these MSS/RDSS feeder links.

4.3 Feeder Links in Other Bands Below 15 GHz (Except 5150-5250 MHz)

The portions of the 6425-6725 MHz bands proposed by three of the pending applicants do not appear to present any insurmountable difficulties for uplink feeder link licensing. However, difficulties may arise with respect to the proposed use of the 5150-5216 MHz downlink band. For this reason, the committee examined all of the downlink FSS bands between 3 and 15 GHz with the view of assessing their utility for feeder links to LEO MSS/RDSS satellites if the 5150-5216 MHz band is not available for such operations.

If this band is not available, the Commission should identify at least one other downlink band between 3 and 15 GHz that would be available for assignment for non-geostationary satellite feeder links to satisfy the feeder link requirements identified. This band would be utilized in conjunction with the proposed uplink feeder link band at 6525-6725 MHz. Based on the preliminary review done by the Committee, it appears that candidates for such alternative feeder link bands would be the 3600-3700 MHz and 10.95-11.20/11.45-11.70 GHz bands. The FSS allotment band at 4500-4800 MHz may also be a candidate from a technical and current usage point of view. However, the existence of the FSS Allotment Plan for this band raises significant regulatory and policy issues.

If no suitable feeder link bands below 15 GHz are available, these applicants may be required to amend their applications to specify the use of bands above 15 GHz for feeder links, despite the substantial

penalties associated with system-design and service-concept modifications.

4.4 Feeder Links in the 20/30 GHz Bands

Feeder links for Iridium will make use of frequencies in the "Ka-band" with a 29.1-29.3 GHz uplink and a 19.4-19.6 GHz downlink. The Iridium feeder-link spectrum requirement is 200 MHz in each of the uplink and downlink band segments. Twelve 6.25 MHz channels within each band segment have been requested. These channels are on an average 15 MHz centers. The system can operate on 7.5 MHz centers.

Feeder links for Odyssey will make use of frequencies in the "Ka-band" with a 29.5-30.0 GHz uplink and a 19.7-20.2 GHz downlink. Within the 500 MHz bandwidth available in each direction, the current Odyssey feeder link spectrum requirement is for approximately 102 MHz. The upper part of the "Ka-band" spectrum has been selected for this (29.895-29.997 GHz uplink; 20.095-20.197 GHz downlink).

Uplinks in the 30 GHz Band

The LEO uplink feeder links of concern are the proposed 200 MHz uplink of the Iridium system at 29.1-29.3 GHz, and the proposed 102 MHz uplink of the Odyssey system at 29.9-30.0 GHz.

The Iridium frequencies overlap the spectrum proposed for use by the uplink for the FSS technology demonstration system ACTS, 28.9-29.8 GHz, and the "B-band" of the Local Multipoint Distribution Service (LMDS) proposed in a recent FCC Notice of Proposed Rule-Making. In addition the band is shared with the fixed service.

With regard to Iridium/FSS sharing, the occurrence of beam coupling which could result in mutual adverse interference between the GSO/FSS system and the Iridium networks can be mutually avoided through one or more techniques. These include: 1) use of band segmentation; 2) the switching of a LEO earth station from one LEO satellite receiver to an alternate; 3) use of alternate gateways (via land line); 4) acceptance of short term outages; 5) acceptance of the interference level. In addition, when coordinating the site of the LEO earth station with that of the FSS earth station an area of geographic isolation (i.e. exclusive geographical service area) can be established within which interference is reduced to acceptable levels.

Most of these options are operational arrangements which may be agreed at the time of licensing and/or coordination if necessary. Several new rules to address the situation are provided in Section 5.

With regard to Iridium/LMDS sharing, the analyses have shown that in major metropolitan areas the LEO earth stations would cause unacceptable interference to a LMDS type of implementation, and the LEO satellite receiver would receive unacceptable interference from a group of LMDS transmissions. Therefore, if the LMDS is to be established, it should be excluded from the 200 MHz proposed to be used by Iridium.

It is not clear to what extent the fixed service will be implemented in the 28.5-29.5 GHz band. To some extent sharing criteria either exist or could be developed and existing coordination methods applied to provide for the coexistence of the fixed and fixed satellite services. However, constraints would have to be put on both services particularly close to major cities, and therefore given the amount of spectrum available, a geographic-based band segmentation of 200 MHz to accommodate the requirement would be the simplest approach to provide for Iridium coexistence with this service.

In the frequency band 29.5-30.0 GHz that is planned for use by the Odyssey system for its Earth-to-space feeder link, the full 500 MHz is allocated on a co-primary basis to the fixed-satellite service and the mobile-satellite service in Region 2. In Regions 1 and 3, the mobile-satellite allocation is co-primary only at 29.9-30.0 GHz (and is secondary at 29.5-29.9 GHz). The Odyssey system requires slightly more than 100 MHz of the preferred band, and would be located at the top end of the frequency range.

In order for Odyssey to share with geostationary fixedsatellite service systems, there are several steps that could be taken to prevent harmful interference from Odyssey earth stations to geostationary FSS satellites. Possible steps include ensuring, if it is possible, that Odyssey orbit ground tracks are such that there is never a direct alignment between the Odyssey earth station and the geostationary FSS satellite (a solution that may be viable when geostationary FSS use of the band remains at its current low levels); coordinating with geostationary FSS systems to mitigate or avoid potential harmful interference from instances of alignment (through control of power levels and avoidance of co-frequency operation); and the use of Odyssey feeder link earth station diversity.

Steps can also be taken to prevent harmful interference from geostationary FSS earth stations to Odyssey satellites. These steps include attempting to avoid direct alignment between Odyssey satellites and the geostationary FSS earth stations; pointing Odyssey satellites' steerable antennas to points on the Earth where there are no transmitting geostationary FSS system earth stations; and coordinating with geostationary FSS systems to mitigate or avoid potential harmful interference from instances of alignment (through control of power levels and avoidance of co-frequency operation).

Sharing with the MSS at 29.5-30.0 GHz should be made possible by the fact that there are only two planned systems in the U.S. (ACTS and NORSTAR-I) and no other existing or planned MSS systems in the band, and by the fact that geostationary MSS systems, unlike geostationary FSS systems, do not receive the added protection afforded by RR 2613. Any interference to Odyssey from MSS service links in the band will be minimized by the likely characteristics of the mobile earth stations. Interference from Odyssey feeder links to MSS service links will have to be coordinated, but the relatively narrow beamwidths of the Odyssey feeder link will help resolve any interference issues.

Downlinks in the 20 GHz Band

Motorola proposes to operate Iridium feeder links (space-to-Earth) in the 18.8-19.7 GHz band, and TRW proposes to operate Odyssey feeder links (space-to-Earth) in the 19.7-20.2 GHz band.

The 18.8-19.7 GHz downlink band is allocated to the FSS on a co-primary basis with the fixed service. The sharing analysis concerns LEO/GSO system and LEO/fixed service sharing.

Techniques for Iridium/GSO downlink sharing are the same as those in the uplink case. There are two situations. The first situation includes use of band segmented frequencies, switching of a LEO earth station receiver from one LEO transmitter to an alternate and acceptance of short term interference. In addition, the location of the LEO earth station can be geographically isolated with respect to the location of existing FSS stations to reduce the signal level into the GSO/FSS receiver. For the second situation, the principal technique is to establish an area of geographic isolation.

The fixed service is protected by PFD limits, and the LEO earth station is protected by separation distances and by coordination provisions in existing FCC rules.

In the frequency band 19.7-20.2 GHz that is planned for use by the Odyssey system for its space-to-Earth feeder link, the full 500 MHz is allocated on a co-primary basis to the fixed-satellite service and the mobile-satellite service in Region 2. In Regions 1 and 3, the mobile-satellite allocation is co-primary only at 20.1-20.2 GHz (and is secondary at 19.7-20.1 GHz). The Odyssey system requires slightly more than 100 MHz of the preferred band, and would be located at the top end of the frequency range.

In order for Odyssey to share with geostationary fixedsatellite service systems, there are several steps that could be taken to prevent harmful interference from Odyssey satellites to geostationary FSS earth stations. Possible steps include attempting to ensure, if it is possible, that Odyssey orbit ground tracks are such that the Odyssey satellites never pass through the beam of the geostationary FSS earth station; locating geostationary FSS earth stations outside the satellite antenna footprint of the Odyssey satellite (a solution that may be made more practical by virtue of the narrow beamwidth of the Odyssey feeder link satellite antenna); and coordinating with geostationary FSS systems to mitigate or avoid potential harmful interference from instances of alignment (through control of power levels and avoidance of co-frequency operation).

Steps can also be taken to prevent harmful interference from geostationary FSS satellites to Odyssey earth stations, including attempting to avoid direct alignment between Odyssey satellites and the geostationary FSS earth stations; locating Odyssey feeder link earth stations outside the coverage area of the geostationary FSS satellite to gain isolation; and coordinating with geostationary FSS systems to mitigate or avoid potential harmful interference from

instances of alignment (through control of power levels and avoidance of co-frequency operation).

Sharing with the MSS at 19.7-20.2 GHz should be aided by the fact that there are relatively few MSS systems planned for the band (i.e. ACTS and NORSTAR-I), and by the fact that geostationary MSS systems, unlike geostationary FSS systems, do not receive the added protection afforded by RR 2613. Any interference to Odyssey from MSS service links in the band will be minimized by the likely characteristics of the mobile earth stations. Any interference from Odyssey feeder links to MSS service links will have to be coordinated.

Co-frequency Sharing

No proponents proposing to use the 20/30 GHz FSS allocations have proposed to use the same allocations. Were such a situation to come about, the most efficient approach to solving the problem would be to provide for additional band segments from available FSS spectrum for each applicant. This approach is warranted, because it has been shown that there are various techniques for LEO and GSO systems to coexist in the FSS allocations, and sharing of the same FSS allocations at this frequency by multiple LEO feeder links has not been analyzed, could be quite complex, and introduce an additional level of constraints.

4.5 Inter-satellite Links in the 23 GHz Band

The issues addressed included use of inter-satellite link allocations, sharing criteria, and future use of inter-satellite link allocations. The analyses indicate that the use of the inter-satellite allocation at 23.18-23.38 GHz band is compatible with NASA's and radio astronomy's use of the 22.55-23.55 GHz allocations, and the fixed service in the same band would be protected. However, NASA prefers that additional MSS applications proposing to use the inter-satellite service should look to the 24.45-24.75 GHz bands for this purpose.

Several new rules are proposed to identify inter-satellite service frequencies, provide for coordination with government agencies, and establish certain sharing criteria.

5.0 RULES AND RECOMMENDATIONS

The Committee recommends that the Commission take account of the analyses that appear in this report and the working group reports attached hereto and act on the rules and recommendations which have received consensus support of the full Committee. A compilation of recommended rule changes appears in section 5.1. Recommendations other than specific rule changes are summarized in section 5.2.

5.1 RULES

5.1.1 unused

5.1.2 Recommended Rules for the Protection of the Radio Astronomy Service against Interference from MSS/RDSS Systems in the 1610.6-1613.8 MHz Band

- (1) Ground-based mobile earth stations will not transmit within the band 1610.6-1613.8 MHz when located within the protection zones defined by the radio observatory coordinates and separation distances specified in Table [25.xxx] during periods of observations in this band as notified to the MSS/RDSS system operator by the Electromagnetic Spectrum Management Unit (ESMU), National Science Foundation, Washington, DC.

For airborne transmitters operating in the 1610.6-1613.8 MHz band, the separation distance shall be the larger of the distance specified in Table [25.xxx] or the distance $d(\text{km})$ as given by the formula:

$$d(\text{km}) = 4.1 \sqrt{h}$$

where h is the altitude of the aircraft in meters above ground level.

A beacon-actuated protection zone may be used in lieu of the fixed protection zones defined in Table [25.xxx] if a coordination agreement is reached between an MSS/RDSS system operator and the Electromagnetic Spectrum Management Unit, National Science Foundation, Washington DC, on the specifics of such beacon operations.

In the absence of a coordinated beacon-actuated protection zone, the MSS/RDSS system shall be capable of providing this protection within the first position fix of the mobile terminal prior to transmission or as soon as practicable after entering into a protection zone.

Discussions between MSS/RDSS operators and ESMU shall be undertaken to avoid scheduling radio astronomy observations during peak MSS/RDSS traffic periods to the greatest extent practicable.

- (2) The radii of the protection zones identified in subsection (1) shall be reduced upon a showing by an MSS operator to the ESMU and good faith agreement that the operation of a mobile earth station will not cause harmful interference to a radio astronomy observatory during periods of observation.
- (3) Additional radio astronomy sites, not located within 100 Miles of the 100 most populous urbanized areas as defined by the United States Census Bureau at the time, may be afforded similar protection one year after notice to the MSS/RDSS system operators and the issue of a public notice by the Commission.

- (4) Each MSS/RDSS system applicant shall include in its application a showing that these requirements will be satisfied.

5.1.3 Feeder Link and Inter-satellite Link Operations Rules

a. Add the definition of "mobile satellite service" to the definitions in Section 25.201, as set forth in Article 1 of the international Radio Regulations.

b. Add new subsection (a)(3) to Section 25.202, as follows:

"(3) Fixed-satellite services frequencies may be used for feeder links between radiodetermination or mobile satellites and feeder link (control center or gateway) earth stations, subject to the Rules in this subpart."

c. Add new Section 25.---, as follows:

"Additional Coordination Obligation for Non-Geostationary and Geostationary Satellite Systems in Frequencies Allocated to the Fixed-Satellite Service.

Operators of non-geostationary satellite systems that use frequency bands allocated to the fixed-satellite service for their feeder link operations shall coordinate their operations with operators of geostationary fixed-satellite service systems licensed by the Commission for operation in the same frequency bands. Operators of geostationary fixed-satellite service systems in the frequency bands that are licensed to non-geostationary satellite systems for feeder link operations shall coordinate their operations with the operators of such non-geostationary satellite systems."

d. In Sections 25.203 (c)(2)(vii), add the following clause to the end of the current text:

* * *

"taking into account the provisions of Section 25.253(a)(2) for earth stations operating with non-geostationary satellites."

e. Add new subsection (j) to Section 25.203, as follows:

"Applicants for non-geostationary MSS/RDSS feeder links in the bands 18.8-20.2 GHz and 27.5-30.0 GHz will indicate the frequencies and spacecraft antenna gain contours towards each feeder-link earth station location and will coordinate with licensees of other FSS and terrestrial-service systems sharing the band to determine geographic protection areas around each non-geostationary MSS/RDSS feeder-link earth station."

f. Add new subsection (k) to Section 25.203, as follows:

"An applicant for an earth station that will operate with a geostationary satellite or non-geostationary satellite in a frequency band in which a non-geostationary system is (or is proposed to be) licensed for feeder links shall demonstrate in its application that

its proposed earth station will not cause unacceptable interference to any other satellite network that is authorized to operate in the same frequency band, or certify that the operations of its earth station shall conform to established coordination agreements between the operator(s) of the space station(s) with which the earth station is to communicate and the operator(s) of any other space station(s) licensed to use the band."

The following Rules concern inter-satellite links:

g. Add new Section 25.---, as follows:

"Inter-satellite Service

- (1) Any non-geostationary satellite communicating with other space stations may use frequencies in the inter-satellite service as indicated in Section 2.106 and does not preclude the use of other frequencies for such purposes as provided for in several service definitions, e.g. FSS. The technical details of the proposed inter-satellite link shall be provided in accordance with 25.114 (c).
- (2) Operating conditions. In order to ensure compatible operations with authorized users in the frequency bands to be utilized for operations in the inter-satellite service, these inter-satellite service systems must operate in accordance with the conditions specified in this section.
 - (a) Coordination requirements with federal government users.
 - (i) In frequency bands allocated for use by the inter-satellite service that are also authorized for use by agencies of the federal government, the federal use of frequencies in the inter-satellite service frequency bands is under the regulatory jurisdiction of the National Telecommunications and Information Administration (NTIA).
 - (ii) The Commission will use its existing procedures for liaison with NTIA to reach agreement with respect to achieving compatible operations between federal government users under the jurisdiction of NTIA and inter-satellite service systems through the frequency assignment and coordination practices established by NTIA and the Interdepartment Radio Advisory Committee (IRAC). In order to facilitate such frequency assignment and coordination, applicants shall provide the Commission with sufficient information to evaluate electromagnetic compatibility with the federal government use of the spectrum, and any additional information requested by the Commission. As part of the coordination process, applicants shall show that they will not cause unacceptable interference to authorized federal government users, based upon existing system information provided by the government. The frequency assignment and coordination of the satellite system shall be completed prior to grant of construction authorization.

- (b) Coordination among inter-satellite service systems. Applicants for authority to establish inter-satellite service are encouraged to coordinate their proposed frequency usage with existing permittees and licensees in the inter-satellite service whose facilities could be affected by the new proposal in terms of frequency interference or restricted system capacity. All affected applicants, permittees, and licensees, shall at the direction of the Commission, cooperate fully and make every reasonable effort to resolve technical problems and conflicts that may inhibit effective and efficient use of the radio spectrum; however, the permittee or licensee being coordinated with is not obligated to suggest changes or re-engineer an applicant's proposal in cases involving conflicts."

h. Add new subsection (a)(4) to Section 25.202, as follows:

"The following frequencies are available for use by the inter-satellite service:

22.55-23.00 GHz
23.00-23.55 GHz
24.45-24.65 GHz
24.65-24.75 GHz

i. Replace subsection (c) to Section 25.208 with the following:

"In the bands 17.7-19.7 GHz, 22.55-23.00 GHz, 23.00-23.55 GHz, 24.45-24.75 GHz, the power flux density at the earth's surface produced by emissions from a space station for all conditions and for all methods of modulation shall not exceed the following values:

-115 dB(W/m²) in any 1 MHz band for angles of arrival between 0 and 5 degrees above the horizontal plane.

-115 + 0.5 (δ -5) dB (W/m²) in any 1 MHz band for angles of arrival δ (in degrees) between 5 and 25 degrees above the horizontal plane.

-105 dB (W/m²) in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

5.2 RECOMMENDATIONS

5.2.1 unused

5.2.2 Other Conclusions and Recommendations on Interservice Sharing

The other conclusions and recommendations of the Committee regarding the 24 cases of interservice interference listed in Table 3-1 are given below.

References in parentheses included with the title of each of the following subsections are to the reports of the drafting groups (DG) of IWG 2; viz, DG2A on protection of the RAS, DG2B on sharing with

the ARNS, and DG2C on sharing with all other services. These reports are included as Attachments A, B, and C, respectively, to the final report of IWG 2 (Doc. MSSAC 42.7 (Rev. 5)).

5.2.2.1 Case 1 - Protection of the Radioastronomy Service (RAS) in the Band 1610.6-1613.8 MHz from In-Band MSS/RDSS Uplink Transmissions

5.2.2.1.1 Fixed protection zone (DG2A Report §6.1.1)

The Committee recommends: 1) that a protection zone of 100-mile (160 km) radius around the Arecibo, PR, Green Bank, WV, VLA (San Augustin, NM), Owens Valley, CA, and Ohio State University, OH radio astronomy observatories listed in Table 3-1 of the DG2A Report, and any others subsequently added under the provisions described below, will protect them from unacceptable interference from uplink transmissions from mobile earth stations (MES) in the band 1610.6-1613.8 MHz; and 2) that such a protection zone be incorporated in the Commissions' Rules.

The Committee also recommends: 1) that a protection zone of 30-mile (50 km) radius around the VLBA observatories listed in Table 3-1 of the DG2A Report, and any others subsequently added under the provisions described below, will protect them from unacceptable interference from uplink transmissions from MES in the band 1610.6-1613.8 MHz; and 2) that such a protection zone be incorporated in the Commission's Rules.

The Committee concludes that an RAS observatory may be deleted from the list of protected sites upon publication of an FCC Public Notice, and added to the list of protected sites one year after publication of such a Public Notice, following notification to the Commission of such deletions and/or additions, by the Electromagnetic Spectrum Management Unit (ESMU), National Science Foundation, Washington, DC 20550, except that Radio Astronomy observatories within 100 miles of the 100 most populous urbanized areas as defined by the U.S. Census Bureau at the time shall not be added to the list of observatories that must be protected.

System operators should be required by the Commission's Rules to include in their applications analyses to demonstrate that MESS in their systems located in, or entering into, a protection zone will be detected within the first position fix of the mobile terminal prior to transmission, or as soon as practicable after entering the protection zone, and assigned, or reassigned, a non-interfering communication channel outside the band 1610.6-1613.8 MHz.

The radius of the protection zone around an observatory, perhaps as a function of azimuth, could be reduced (never increased) by coordination with the operator of that observatory, or by the use of a beacon-actuated protection zone as described below.

5.2.2.1.2 Beacon-actuated protection zone (DG2A Report §6.1.3)

Beacon-actuated protection zones could provide an acceptable alternative to fixed protection zones for operating MES near RAS observatories. However, the concerns discussed above must be worked out to demonstrate the practical, technical, and economic feasibility of the beacon concept as an alternative to protection zones of specified radius around designated RAS sites. Since implementation of MSS/RDSS systems will undoubtedly take a few years, there will be time to resolve these questions.

In order for this approach to work in practice, there must be close coordination between the MSS system proponent and the RA community. Accordingly, the Commission should adopt a rule which would require any MSS licensee that proposes to rely upon such a beacon approach to coordinate its system design, testing, and operating procedures through the Electromagnetic Spectrum Management Unit (ESMU) of the National Science Foundation, CORF, or other suitable entity designated by the radio astronomy community. The Commission should also require that all parties negotiate suitable agreements in good faith and on a timely basis.

In summary, a beacon-actuated protection zone could be used in lieu of the protection zone of specified radius around an RAS observatory following coordination of the specific beacon system to be employed with the operator of that observatory.

5.2.2.2 Case 2 - Protection of the RAS in the Band 1610.6-1613.8 MHz from MSS/RDSS Uplink Transmissions Outside This Band: Fixed Protection Zone (DG2A Report §6.1.2)

The Committee concludes that fixed protection zones could be established for out-of-band MSS uplinks in the bands immediately adjacent to the 1610.6-1613.8 MHz band with radii smaller than those for in-band cases given in §5.2.2.1 above, and that no protection zones are needed when uplink transmissions are located sufficiently far from the edge of the 1610.6-1613.8 MHz band, provided out-of-band emissions of the MES fall off sufficiently rapidly.

The radii of the fixed protection zones for out-of-band transmissions for non-VLBA sites are determined on the hypothesis that the 100 statute miles radius is a standard for cochannel protection from MES signals with a transmitted e.i.r.p. density of -55 dBW/Hz. We note that with the assumed propagation model, a power of -65 dBW/Hz will produce a flux density at the radioastronomy antenna of -238 dBW/m²Hz. Under some assumptions, this level could cause harmful interference, but the aforementioned standard has been agreed to as a practical criterion.

Figures 6-1 and 6-2 of the DG2A Report show for purposes of illustration the variation from this transmitted power permissible as a function of the radius of the protection zone. Attenuation as a function of distance has been calculated using the Okumura propagation model for open terrain as a working hypothesis. Such use extends the model beyond its normal range of validity; as better

models valid over a wider range become available, they should be used.

By way of example, note that if the transmitted power is 10 dB less than the reference value, then the protection zone can be reduced to about 75 miles. A cochannel reduction in power might take place by lowering the transmitter power and an out-of-band reduction because of filtering. Figure 6-3 of the DG2A Report shows the effects of such filtering on out-of-band emissions for three different, but representative, Butterworth filters. The filter and propagation curves can be combined, as in Figure 6-4 of the DG2A Report, to show directly the relation between protection zone radius and frequency offset.

Note that the curves do not go below 1.0 km because the Okumura model is not valid at such short distances. However, it would be desirable to permit operation of MES, even on the grounds of astronomical observatories, if it can be shown that they will not cause interference. It is to be hoped that values for such close ranges will be proposed by one or more of the parties responding to the Commission's NPRM for MSS/RDSS systems above 1.0 GHz, which will be issued in due course.

Figures 6-5 and 6-6 of the DG2A Report are repeats of the first two figures but based on the 30-mile radius protection zone recommended for in-band interference at VLBA observatories.

The attention of the FCC is drawn to the potential impact of providing this level of protection from out-of-band emissions on the various MSS/RDSS sharing approaches under consideration by IWG 1. Likewise, the FCC may wish to consider the impact on system cost of providing the out-of-band signal suppression needed to keep the size of the protection zone acceptably small.

5.2.2.3 Case 3 - Protection of the RAS in the Band 1610.6-1613.8 MHz from MSS Secondary Downlink Transmissions in the Band 1613.8-1626.5 MHz (DG2A Report §6.2.1)

The Committee recommends that the spectral power flux-density (PFD) reaching the surface of the earth in the band 1610.6-1613.8 MHz from out-of-band emissions from all satellites in an MSS/RDSS system in the band 1613.8-1626.5 MHz not exceed -238 dB(W/m²Hz) during observations at the non-VLBA sites to be protected, and -198 dB(W/m²Hz) during observations at the VLBA sites to be protected.

The Committee believes that system operators can comply with this limit through a combination of high-pass filters in the satellite transmitter, and/or employment of a guard band between the lowest satellite channel to be used and the upper edge of the protected band, 1613.8 MHz.

The Committee recommends that prospective MSS/RDSS system operators establish that they can meet these requirements through analyses and testing. These analyses and test data should be